

CLAIMS

What is claimed is:

1 1. A method for inspecting a press-fit connection, the method comprising:
2 capturing an image of a circuit board location at which a pin is to have been
3 press-fit;
4 identifying a feature in a captured image that may comprise a tip of the pin;
5 measuring characteristics that pertain to particular features of the identified pin
6 tip;
7 comparing the measured characteristics with at least one of stored reference
8 values and each other; and
9 making a final decision as to whether the press-fit connection is acceptable
10 based upon results of the comparing.

1 2. The method of claim 1, wherein capturing an image comprises
2 capturing an image of a flat end surface of the pin tip and separately capturing an
3 image of at least one chamfered surface of the pin tip.

1 3. The method of claim 2, further comprising forming a composite image
2 that comprises data from the captured image of the flat end surface and the captured
3 image of the at least one chamfered surface.

1 4. The method of claim 2, wherein capturing an image of the flat end
2 surface comprises illuminating the pin with light that is emitted nearly perpendicular
3 to the circuit board and capturing an image of the at least one chamfered surface
4 comprises illuminating the pin with light that is emitted nearly parallel to the circuit
5 board.

1 5. The method of claim 4, wherein illuminating the pin with light that is
2 emitted nearly perpendicular comprises emitting light at an angle of approximately 70
3 degrees away from a plane that is parallel with a plane of the circuit board.

1 6. The method of claim 4, wherein illuminating the pin with light that is
2 emitted nearly parallel comprises emitting light at an angle of approximately 15
3 degrees away from a plane that is parallel with a plane of the circuit board.

1 7. The method of claim 1, wherein identifying a feature in a captured
2 image comprises performing correlation pattern matching to identify a match in the
3 captured image with a pin tip model.

1 8. The method of claim 1, wherein measuring characteristics comprises
2 defining an image analysis line that crosses the pin tip and measuring pixel intensity
3 along the length of the defined line.

1 9. The method of claim 1, wherein measuring characteristics comprises
2 measuring a dimension of at least one of a flat end surface and a chamfered surface of
3 the pin tip.

1 10. The method of claim 1, wherein measuring characteristics comprises
2 measuring a peak pixel intensity of at least one of a flat end surface and a chamfered
3 surface of the pin tip.

1 11. The method of claim 1, wherein measuring characteristics comprises
2 measuring a position at which a peak pixel intensity occurs for at least one of a flat
3 end surface and a chamfered surface of the pin tip.

1 12. The method of claim 1, wherein comparing the measured
2 characteristics comprises comparing a dimension of at least one of a flat end surface
3 and a chamfered surface of the pin tip with a reference value.

1 13. The method of claim 1, wherein comparing the measured
2 characteristics comprises comparing a peak pixel intensity of at least one of a flat end
3 surface and a chamfered surface of the pin tip with a reference value.

1 14. The method of claim 1, wherein comparing the measured
2 characteristics comprises comparing a position of a peak pixel intensity of a
3 chamfered surface of the pin tip with a position of a peak pixel intensity of a flat end
4 surface of the pin tip.

1 15. The method of claim 1, wherein making a final decision comprises
2 weighting the results so that the results that are most highly indicative of whether the
3 press-fit connection is or is not acceptable is given greater weight than other results.

1 16. A system for inspecting a press-fit connection, the system comprising:
2 means for illuminating a pin tip from two distinct directions, a first direction
3 suited to illuminate a flat end surface of the pin tip and a second direction suited to
4 illuminate at least one chamfered surface of the pin tip;

5 means for capturing a first image while the pin tip is illuminated with light
6 from the first direction and a second image while the pin is illuminated with light
7 from the second direction;

8 means for measuring characteristics from image data of the captured images
9 that pertain to a flat end surface and at least one chamfered surface of the pin tip; and

10 means for comparing the measured characteristics with at least one of stored
11 reference values and each other.

1 17. The system of claim 16, wherein the means for illuminating comprise a
2 lighting head that is adapted to emit light in a direction nearly perpendicular to a plane
3 of a circuit board in which the pin is inserted and a direction nearly parallel to the
4 plane of the circuit board.

1 18. The system of claim 16, wherein the means for capturing comprise a
2 two-dimensional camera.

1 19. The system of claim 16, wherein the means for measuring comprise an
2 image analysis system that is configured to define an image analysis line that crosses
3 the pin tip and that measures pixel intensity along the length of the defined line.

1 20. The system of claim 19, wherein the image analysis system is
2 configured to measure a dimension of at least one of the flat end surface and the at
3 least one chamfered surface.

1 21. The system of claim 16, wherein the means for comparing comprise an
2 image analysis system that is configured to compare a dimension of at least one of the
3 flat end surface and the at least one chamfered surface with a reference value.

1 22. The system of claim 16, wherein the means for comparing comprise an
2 image analysis system that is configured to compare a peak pixel intensity of at least
3 one of the flat end surface and the chamfered surface with a reference value.

1 23. The system of claim 16, wherein the means for comparing comprise an
2 image analysis system that is configured to compare a position of a peak pixel
3 intensity of a chamfered surface with a position of a peak pixel intensity of the flat
4 end surface.

1 24. The system of claim 16, further comprising means for identifying the
2 pin tip in the composite image.

1 25. The system of claim 16, further comprising means for making a final
2 decision as to whether the press-fit connection is acceptable based upon results
3 obtained by comparing the measured characteristics with at least one of stored
4 reference values and each other.

1 26. An inspection system stored on a computer-readable medium, the
2 system comprising:

3 logic configured to identify a tip of a pin that has been press fit into a circuit
4 board;

5 logic configured to measure characteristics that pertain to a flat end surface
6 and a chamfered surface of an identified pin tip;

7 logic configured to compare measured characteristics with at least one of
8 stored reference values and each other; and

9 logic configured to make a final decision as to whether the pin is properly
10 installed based upon results of the comparing performed by the logic configured to
11 compare.

1 27. The system of claim 26, wherein the logic configured to identify a tip
2 of a pin comprises logic configured to perform correlation pattern matching to
3 identify a match in the image with a pin tip model.

1 28. The system of claim 26, wherein the logic configured to measure
2 characteristics comprises logic configured to define an image analysis line that
3 crosses the pin tip and to measure pixel intensity along the length of the defined line.

1 29. The system of claim 26, wherein the logic configured to measure
2 characteristics comprises logic configured to measure dimensions of the flat end
3 surface and the chamfered surface.

1 30. The system of claim 26, wherein the logic configured to measure
2 characteristics comprises logic configured to measure peak pixel intensities of the flat
3 end surface and the chamfered surface.

1 31. The system of claim 26, wherein the logic configured to measure
2 characteristics comprises logic configured to measure positions at which a peak pixel
3 intensities occur for the flat end surface and the chamfered surface.

1 32. The system of claim 26, wherein the logic configured to compare
2 measured characteristics comprises logic configured to compare dimensions of the flat
3 end surface and the chamfered surface with reference values.

1 33. The system of claim 26, wherein the logic configured to compare
2 measured characteristics comprises logic configured to compare peak pixel intensities
3 of the flat end surface and the chamfered surface with reference values.

1 34. The system of claim 26, wherein the logic configured to compare the
2 measured characteristics comprises logic configured to compare a position of a peak
3 pixel intensity of the flat end surface with a position of a peak pixel intensity of the
4 chamfered surface.

1 35. The system of claim 26, wherein the logic configured to make a final
2 decision comprises logic configured to weigh comparison results so that the results
3 that are most highly indicative of whether the pin is or is not properly installed is
4 given greater weight than other results.

1 36. A system for inspecting a press-fit connection, the system comprising:
2 a camera adapted to capture images of a circuit board to be inspected;
3 a lighting head that is adapted to emit light in a direction nearly perpendicular
4 to the circuit board and in a direction nearly parallel to the circuit board; and
5 an image analysis system configured to identify a tip of a pin that has been
6 press fit into the circuit board, to measure characteristics that pertain to a flat end
7 surface and a chamfered surface of the identified pin tip, to compare the measured
8 characteristics with at least one of stored reference values and each other, and to make
9 a final decision as to whether the pin is properly installed based upon results of the
10 comparing.

1 37. The system of claim 36, wherein the camera is a charge-coupled
2 device.

1 38. The system of claim 36, wherein the lighting head emits light at an
2 angle of approximately 70 degrees relative to a plane parallel to a plane of the circuit
3 board and an angle of approximately 15 degrees relative to another plan parallel to the
4 plane of the circuit board.

1 39. The system of claim 36, wherein the image analysis system is
2 configured to measure at least one of dimensions of the flat end surface and the
3 chamfered surface, peak pixel intensities of the flat end surface and the chamfered
4 surface, and positions at which a peak pixel intensities occur for the flat end surface
5 and the chamfered surface.

1 40. The system of claim 36, wherein the image analysis system is
2 configured to compare at least one of dimensions of the flat end surface and the
3 chamfered surface, peak pixel intensities of the flat end surface and the chamfered
4 surface with reference values, and positions of peak pixel intensities of the flat end
5 surface and the chamfered surface with reference values.

1 41. The system of claim 36, wherein the image analysis system is
2 configured to compare a position of a peak pixel intensity of the flat end surface with
3 a position of a peak pixel intensity of the chamfered surface.

1 42. A method for inspecting connection of an element to a circuit board,
2 the method comprising:

3 identifying a feature in a captured image that may comprise a known feature
4 of the element;

5 measuring characteristics of the identified feature;

6 comparing the measured characteristics with at least one of stored reference
7 values and each other; and

8 making a final decision as to whether the connection is acceptable based upon
9 results of the comparing.

1 43. The method of claim 42, further comprising forming a composite
2 image that comprises data from two separate captured images, a first image captured
3 when the element is illuminated from a first direction, and a second image captured
4 when the element is illuminated from a different direction.

1 44. The method of claim 43, wherein forming a composite image
2 comprises emitting light nearly perpendicular to the element to capture the first image
3 and emitting light nearly parallel to the element to capture the second image.

1 45. The method of claim 42, wherein identifying a feature comprises
2 performing correlation pattern matching to identify a match in the captured image
3 with a model of the feature.

1 46. The method of claim 42, wherein comparing the measured
2 characteristics comprises comparing a dimension of an identified feature with a
3 reference value.

1 47. The method of claim 42, wherein comparing the measured
2 characteristics comprises comparing a peak pixel intensity of an identified feature
3 with a reference value.

1 48. The method of claim 42, wherein making a final decision comprises
2 weighting the results so that the results that are most highly indicative of whether the
3 connection is or is not acceptable is given greater weight than other results.

1 49. An inspection system stored on a computer-readable medium, the
2 system comprising:

3 logic configured to identify a feature of an element that has been connected a
4 circuit board;

5 logic configured to measure characteristics of the identified feature;

6 logic configured to compare measured characteristics with at least one of
7 stored reference values and each other; and

8 logic configured to make a final decision as to whether the element is properly
9 installed based upon results of the comparing.

1 50. The system of claim 49, wherein the logic configured to identify a
2 feature comprises logic configured to perform correlation pattern matching to identify
3 a match in the image with a model of the feature.

1 51. The system of claim 49, wherein the logic configured to compare
2 measured characteristics comprises logic configured to compare dimensions of the
3 feature with reference values.

1 52. The system of claim 49, wherein the logic configured to compare
2 measured characteristics comprises logic configured to compare peak pixel intensities
3 of the feature with reference values.

1 53. The system of claim 49, wherein the logic configured to make a final
2 decision comprises logic configured to weigh comparison results so that the results
3 that are most highly indicative of whether the element is or is not properly installed is
4 given greater weight than other results.

1 54. An inspection system, comprising:
2 a camera adapted to capture images;
3 a first lighting source that is configured to illuminate an object from a first
4 direction;
5 a second lighting source that is configured to illuminate the object from a
6 second direction; and
7 an image analysis system configured to control the camera so as to capture a
8 first image of the object when illuminated by the first lighting source and capture a
9 second image of the object when illuminated by the second lighting source, the image
10 analysis system further being configured to measure characteristics of the object and
11 compare the measured characteristics with at least one of stored reference values and
12 each other for purposes of making a final decision as to the object.

1 55. The system of claim 54, wherein the camera is a digital camera.

1 56. The system of claim 54, wherein the first and second light sources
2 comprise part of a lighting head.

1 57. The system of claim 54, wherein the first light source emits light at an
2 angle of approximately 70 degrees relative to a plane perpendicular to an optical axis
3 of the camera and the second light source emits light an angle of approximately 15
4 degrees relative to that plane.

1 58. The system of claim 54, wherein the image analysis system is
2 configured to measure at least one of dimensions of the object, peak pixel intensities of
3 the object, and positions at which a peak pixel intensities occur for the object.

1 59. The system of claim 54, wherein the image analysis system is
2 configured to compare at least one of dimensions of the object, peak pixel intensities
3 of the object, and positions of peak pixel intensities of the object.